MatchID
Metrology beyond colors

KU LEUVEN

Application Note

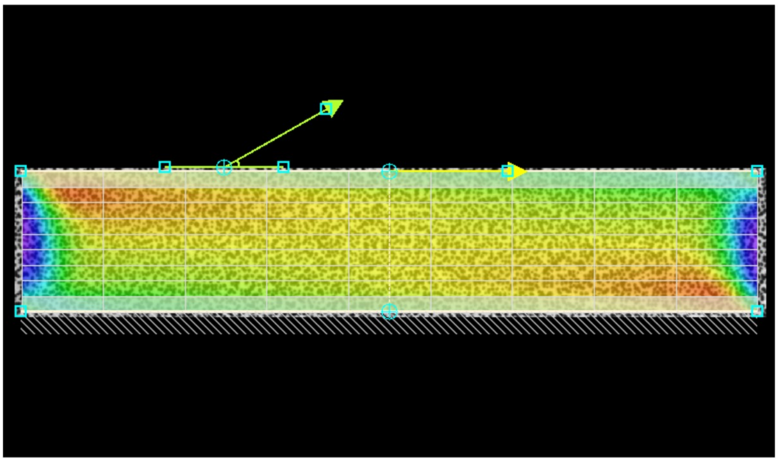
VForm-xSteels

Simulate the identification of anisotropic plasticity in a shear test configuration

Case Description

A virtual shear test is created with an FEA solver adopting benchmark Hill48 –Swift material parameters and material orientation in collaboration with the ELOOI lab from KULeuven. Next, the nodal displacements are used to numerically deform images according to a realistic test setup. This image set is accordingly analyzed via Digital Image Correlation (DIC).

Seamlessly, the Virtual Fields Method (VFM) is invoked to identify the material parameters. Accuracy of the procedure and the impact of the test geometry and DIC filtering process on the retrieved parameters can be evaluated by comparing to the initial input parameters.



Virtual Experiment

- ✓ **FEA:** Abaqus S4R
- ✓ **Material Model:** Hill48
- ✓ **Camera Resolution:** 5MPx
- ✓ **Load Steps**: 50
- ✓ **MI-FEDEF**: Synthetic images with 1% of grey level noise

Analysis

- ✓ **Signal To Noise:** determine optimum DIC settings via PA module
- ✓ **Type:** Stereo DIC
- ✓ **Material Identification:** Virtual Fields method adopting uniform and sensitivity fields

Results

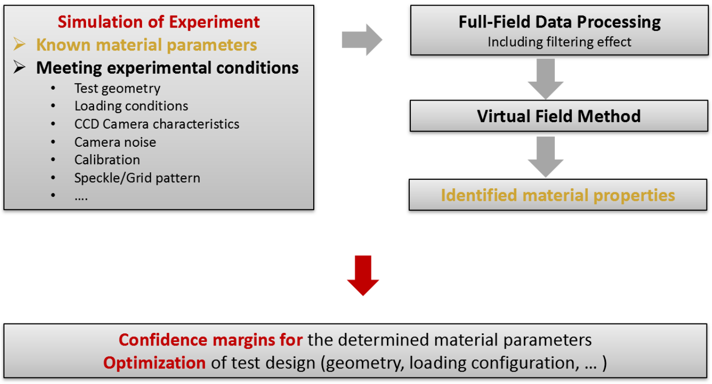
- ✓ **Yield criteria**: von Mises, Hill48, YLD2000-2D, Cazacu 2006
- ✓ **Hardening:** Swift law
- ✓ **Reconstructed stresses**

Why MatchID

- ✓ Unique platform to analyze identification procedures via **virtual experiments and synthetic images**
- ✓ Identification of material properties via the Virtual Fields Method: **reduced number of tests**
- ✓ **Large library** of embedded material models
- ✓ Direct **stress reconstruction** from a full-field perspective

Virtual Experiment

In order to validate the material identification chain relying on DIC and VFM, a virtual shear experiment is created. An Abaqus S4R model with benchmark Hill48—Swift material properties imposing an off-axis rolling direction of 30 degrees yields nodal displacements at various load steps. Next, the MatchID FEDEF module is used to numerically deform a DIC reference speckle image for every step involved. Hereby, typical experimental conditions are incorporated. These virtual images are then processed via our DIC engine, subjecting them to the typical low-pass filtering effects DIC encompasses. The retrieved DIC displacements feed the VFM method and the identified material parameters can be confronted to the benchmark ones of the FEA simulation. This allows for test optimization and accuracy estimation.



M. Rossi, P. Lava, F. Pierron, D. Debruyne, M. Sasso (2015). *Strain, 51 (3), 206-222.*

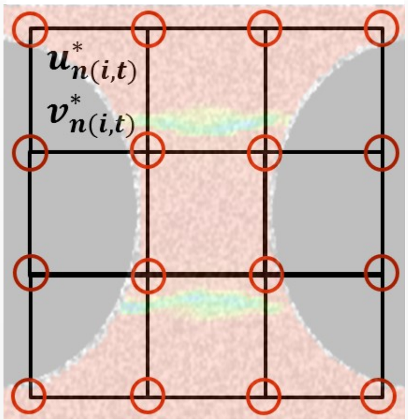
The Virtual Fields Method

The Virtual Fields Method is a semi-analytical approach relying on the principle of virtual work and allows to identify material properties based on full-field data. Accordingly, less tests need to be performed since the stress field is allowed to be heterogeneous compared to traditional tensile testing. It has shown to be way faster than typical Finite-Element Model Updating (FEMU) procedures.

In the MatchID software two types of virtual fields can be adopted: (1) uniform fields giving equal weight to each data point (2) sensitivity-based fields that will put more stress on data points with a higher parameter sensitivity and signal-to-noise robustness. Secondly, the fields are adjusted in order to allow the usage of the total force measured by the load cell, in contrast to FEMU strategies that generally need a quantification of the force or displacement distribution along the clamping.

$$\left[\overbrace{\int_S \left(\int_0^t \mathbf{M}\boxed{\dot{\varepsilon}}\, d\tau \right) . \boldsymbol{\varepsilon}^* \, dS}^{W^*_{int}} - \overbrace{\int_{L_f} \bar{\mathbf{T}}.\mathbf{u}^* \, dl}^{W^*_{ext}}\right]^2 = 0$$

Measured by DIC at every time t



A. Marek, F. M. Davis, J.-H. Kim, F. Pierron (2020). *Experimental Mechanics 60:639–664.*

Identified Results

The VFM identification is applied adopting four different yield criteria: von Mises, Hill48, YLD2000-2D, Cazacu 2006. Equilibrium between external and internal work is established at every load step. The identified parameters are within a 5% error for uniform resp. 1% error for sensitivity-based virtual fields w.r.t. the Hill48 model.

F	H	N	K [MPa]	ε_0	n	r0	r45	r90	Residual	Iterations
0.2391	0.7276	1.348	525.5	0.005614	0.274	2.671	2.135	3.043	0.0001259	300

Charts give informative insight into the stress-strain curves, the evolution of every parameter, the stress space and the equilibrium of work. Finally, full-field stress fields are generated within both the material frame as in the global DIC frame.